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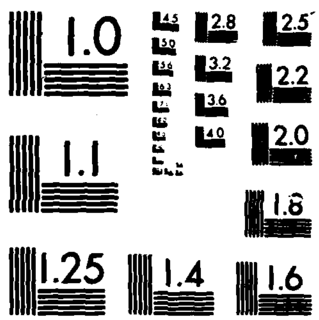

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PROJECT STEAMER: VII. A COMPUTER-BASED SYSTEM FOR MONITORING THE BOILER LIGHT-OFF PROCEDURE FOR A 1078-CLASS FRIGATE

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San Diego, California 92152

NPRDC Technical Note 82-25 August 1982

PROJECT STEAMER: VII. A COMPUTER-BASED SYSTEM FOR MONITORING THE BOILER LIGHT-OFF PROCEDURE FOR A 1078-CLASS FRIGATE

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A computer-based tutorial system that monitors and critiques students' execution of a steam propulsion plant procedure was implemented in the LISP programming language. The system responds to student commands, acknowledging those actions that are appropriate and providing explanation when a student orders actions that are not appropriate.

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FOREWORD

This research and development was conducted in support of Navy decision coordinating paper Z1177-PN (Advanced Computer-aided Instruction), subproject Z1177-PN.03 (STEAMER: Advanced Computer-based Training for Propulsion and Problem Solving). It was sponsored by the Chief of Naval Operations (OP-01). The main objective of the STEAMER effort is to develop and evaluate advanced knowledge-based techniques for use in low-cost portable training systems. The project is focused on propulsion engineering as a domain in which to investigate these computer-based training techniques.

This report is the seventh in a series on the STEAMER project. Previous reports described an initial framework for developing techniques for automatically generating explanations of how to operate complex physical devices; a user's manual for the STEAMER interactive graphics package; a method for generating explanations using qualitative simulation; CONLAN, a constraint-based programming language well suited for describing and analyzing complex devices; a mathematical simulation of the STEAMER propulsion plant; and the then-current STEAMER prototype and basic support software (NPRDC TNs 81-21, 81-22, 81-25, 81-26, 81-27, and TR 82-28). This report describes a computer-based training system for monitoring a student's execution of a boiler light-off procedure and providing tutorial feedback concerning student actions. An expert operator's knowledge of the plant is simulated rather than the plant's physical state. The intended users of this series of reports are designers of procedures training software systems.

Appreciation is expressed to Mike Williams, Zerox Corporation, who participated in discussions about this research.

JAMES F. KELLY, JR.
Commanding Officer

JAMES J. REGAN
Technical Director

SUMMARY

Problem

The STEAMER project, of which this work is a part, is intended to provide computer-based instruction in propulsion engineering. Propulsion engineering personnel must be able to understand and execute hundreds of procedures. A large number of questions concerning ways in which a computer-based instruction system could provide tutorial advice on the execution of procedures remain to be answered.

Objective

The objective of this work is to build a prototype computer-based system that can monitor a student's execution of a procedure and provide meaningful feedback concerning the actions taken by the student. The feedback itself should be in a form similar to the tutorial comments that could be expected from a human expert.

Approach

The sequencing of actions in a procedure is determined, to a large extent, by the fact that the successful execution of any given action may depend upon the prior completion of other actions. System experts frequently base their complaints about violations of procedural sequence and justification of the correct sequence of actions in a procedure in terms of these dependencies among the actions taken. The approach taken was to identify the conceptual relationships among the action steps that constitute a complex propulsion procedure and embody those relationships in an interactive computer program. The program thus simulates an expert operator's understanding of a plant rather than simulating the physical states of the plant itself.

Results

A system was constructed that can monitor the execution of the boiler light-off procedure for a 1078-class frigate. The program responds to the student's commands, acknowledging those actions that are appropriate to the state of the plant, and explaining what is wrong when a student orders an action that is not appropriate.

Conclusions

It is possible to provide considerable tutorial power in a simple system that does not actually simulate the physical plant. A computer-based tutor based on this dependency technique promises to be a fruitful approach to the problems of automating human-like explanation. It also brings to light a number of problems with this approach. There appear to be limits on the degree to which the appropriateness of actions can be inferred from the other actions that have been taken without explicitly representing some aspects of the state of the plant. The process of eliciting knowledge from a subject matter expert (SME) and building the code that embodies that knowledge in the program is quite tedious for both researcher and SME.

Future Research

A facility for critiquing a student's procedural performance has been completed. Another type of tutorial interaction could be achieved by building a justification facility that a student could use to query the system about the reasons for the sequence of actions in the procedure. This would be, in effect, an engineering operation sequencing system

(EOSS) that could explain itself. At present, it is difficult to elicit the knowledge required to implement such a system from SMEs. It is possible that much of the work of eliciting this knowledge and building the computer code that embodies it could be automated. Such an elicitation facility would make the tutorial techniques developed in this work more readily available to a wider community of users.

Recommendations

1. The existing system should be moved to the hardware system that presently supports the STEAMER simulation system.

2. Dependency-based tutorial systems for other procedures should be implemented to test the extensibility of this approach.

3. The problems identified in the attempts to implement the prototype system should be given further attention.

4. The system should be extended so that it will support a justification of the sequence of steps in addition to complaining when a legitimate procedural sequence is violated.

CONTENTS

INTRODUCTION

Problem

The STEAMER project, of which this work is a part, is intended to provide computer-based instruction in propulsion engineering. In an earlier phase of the project, a reactive learning environment for propulsion training was created, consisting of a high quality graphics interface to a mathematical model simulating the thousands of components in a naval steam propulsion plant (Stead, 1981). The next phase of the project is intended to build a computer coaching facility into the same computer. A primary problem in this effort is the identification of techniques appropriate for representing and using human-like expertise upon which the computer tutorial capabilities can be based.

Purpose

Propulsion engineering personnel must be able to understand and execute hundreds of procedures. The objective of this work was to build a computer-based system that can monitor a student's execution of a procedure and provide meaningful feedback concerning the actions taken by the student. The feedback itself was to be in a form similar to the tutorial comments that could be expected from a human expert.

Background

This work is part of the STEAMER project (Advanced Computer-based Training for Propulsion and Problem Solving, Z1177-PN.03). The early phases of the STEAMER program were concerned with building an inspectable simulation of the operation of a steam propulsion plant. That effort provided a mathematical model of a complete propulsion plant and permitted a student to interact with the running model via a library of color graphics diagrams of the plant and its components (Roberts & Forbus, 1981; Hollan, Stevens, & Williams, 1980). Such a facility provides an important type of training for the student of propulsion engineering but does not provide him with the sort of explanations and guidance that a human tutor can. The work described in this report is a preliminary effort to build an interactive expert tutor facility that can be integrated into the existing physical plant simulation system.

During the past decade, a number of computational techniques have been developed in an attempt to provide computer-based tutorial facilities. These include traditional frame-oriented CAI, expert systems such as MYCIN (Shortliffe, 1976), and simple data base systems such as SCHOLAR (Carbonnel, 1970). Perhaps the most ambitious solution is the qualitative modeling scheme of the SOPHIE project. Brown, Burton, and deKleer (1982) describe the most advanced version of that system for training electronics trouble-shooting for a relatively simple amplifier circuit. The explanatory power of the SOPHIE system was based on qualitative models of the circuit's behavior. This project also pioneered the use of a simulation-based reactive learning environment for training and served as a conceptual basis for the STEAMER project. Consideration was given to developing similar qualitative knowledge for reasoning about the behavior of a steam plant. However, the complexity of the steam plant itself and the nature of the interconnections between its components put such a project beyond our immediate capabilities. It is therefore desirable to develop other knowledge representation schemes that can accomplish a portion of the explanation process, without committing system builders to an intractable body of concepts to represent.

APPROACH

The sequencing of actions in a procedure is determined, to a large extent, by the fact that the successful execution of any given action may depend upon the prior completion of other actions. For example, before fires can be lit in the boiler, the steam drum must be prepared, the fuel system must be aligned, and combustion air must be available in the furnace. An attempt to light fires in the boiler when any of these preconditions has not been met is an error. System experts frequently base their complaints about violations of procedural sequence and justification of the correct sequence of actions in a procedure in terms of these dependencies among the actions taken.

The sequence of orders given by the engineering officer of the watch (EOOW) in the lightoff procedure is shown in Appendix A. Each of these orders may require the individual watchstanders in the space to execute many actions. Having decided upon a procedure to use as a base for the tutorial system, the dependencies among the actions in the procedure were analyzed.

A graphic representation of the dependencies among procedural actions is shown in Figure 1. Each arc in the dependencies graph represents a conceptual relationship between a pair of acts. The graph was used as an elicitation frame to capture the subject matter expert's (SME's) knowledge of these relationships. For each arc in the graph, the SME was asked: "Why is it not appropriate to do <the act at the base of the dependency arc> before <the act at the head of the dependency arc>?" The reasons given for each dependency, which we refer to as complaints (see Appendix B), were recorded and stored in the program data structure so that they could be retrieved when appropriate.

RESULTS AND DISCUSSION

A system was constructed that can monitor the execution of the boiler light-off procedure for a 1078-class frigate. The program responds to the student's commands, acknowledging those actions that are appropriate to the state of the plant, and explaining what is wrong when a student orders an action that is not appropriate.

The simulated state of the plant at any given time is entirely dependent upon the set of actions that have been executed up to that point. For any step in the procedure, therefore, the determination of whether or not it is appropriate is based entirely upon whether or not all of the steps on which it depends have been executed. If all of a given step's preconditions have been executed, its execution is deemed appropriate. If one or more of its preconditions has not yet been executed, an attempt to order that step is deemed inappropriate.

The program responds to the student's commands in the following ways (see Appendix C for examples of these responses). If the student chooses an action for execution that is appropriate given the present state of the plant, an acknowledgement of the order using the vocabulary of the engineering spaces is presented to the student. If the student orders an action that is not appropriate given the present state of the plant, the student sees an explanation of why attempting that act at that time is incorrect. The explanation will refer to one or more of the unexecuted preconditions of the selected act. Finally, if the student orders an action that has already been completed, the system informs him of that fact.

The implementation of the dependency analysis as a computer-based tutor (Appendix D gives the LISP code) has the potential to provide a system that is perceived by the user

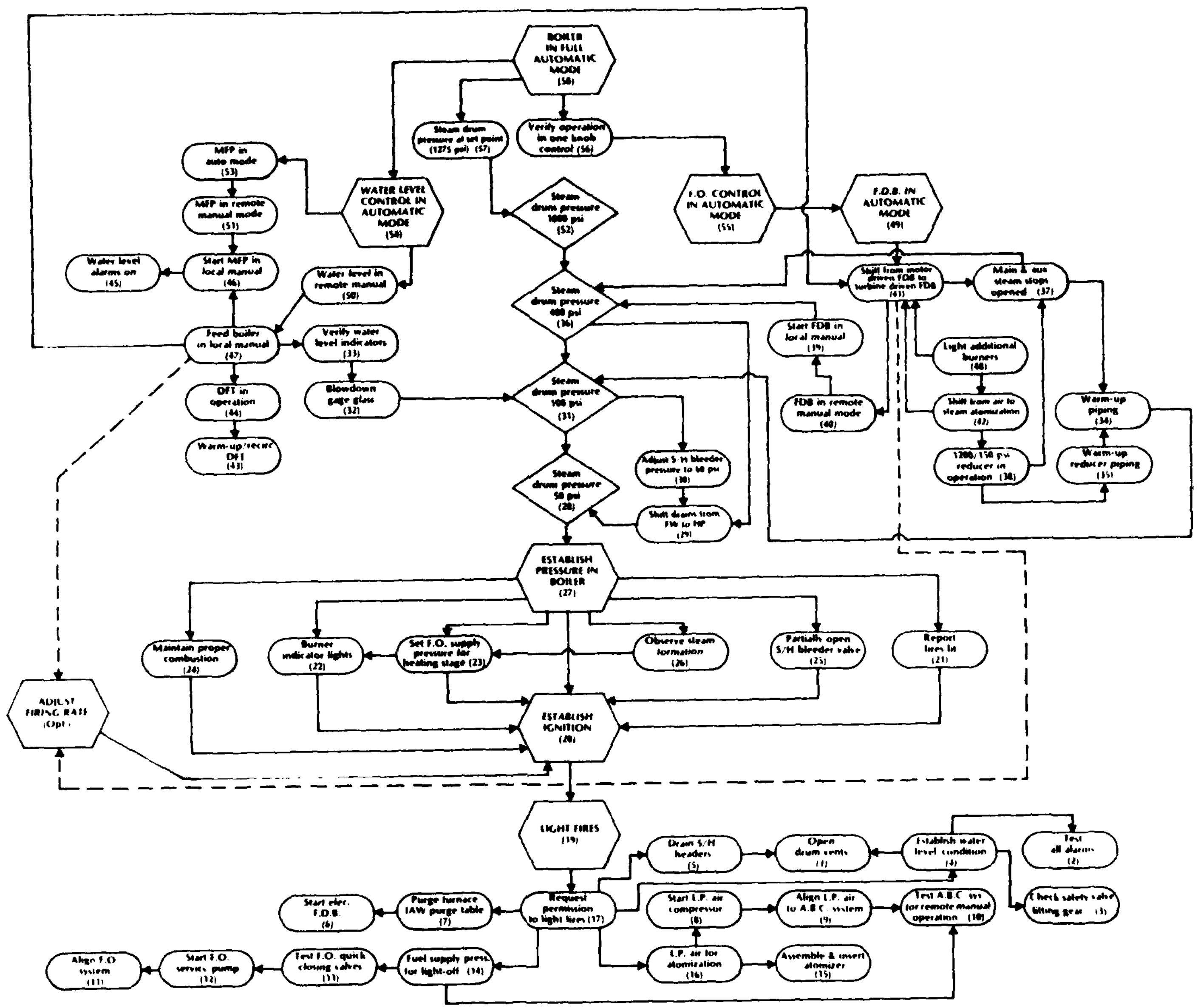

Figure 1: Dependency Diagram for Light-off Actions

to be informative and credibly intelligent. Since it does not actually represent and reason with qualitative knowledge about the plant's behavior, it cannot closely approximate the level of tutorial advice expected from a human tutor. However, given the simplicity of the approach and the relatively small amount of system building required to make it work, it behaves in a surprisingly useful way.

The implementation of this system has also brought to light a number of problems with this approach. These have to do with the representation of states of the plant, the elicitation of knowledge from SMEs, the nature of system responses to unexpected student actions, and the strategies for presenting feedback to the student.

There appear to be limits on the degree to which the appropriateness of actions can be inferred from the other actions that have been taken without explicitly representing some aspects of the state of the plant. For example, some processes in a steam plant cause changes in the state of the plant over time without any explicit intervention of the operator (e.g., the buildup of steam pressure in the steam drum). A dependency representation such as is used here fails to capture such states of the plant.

The process of eliciting knowledge from the SME and building the code that embodies that knowledge in the program is quite tedious for both researcher and SME. Thus, the possibilities of automating the elicitation process such that the system will build the necessary code on the basis of interaction with SMEs are being explored.

Because all of the dependencies are local to actions that are ordered, the system has difficulty giving credible (meaningful) criticism when a student chooses an action that is irrelevant to the current stage of procedure execution. One possible solution would be to represent landmark states that subsume subsets of the procedure under global goals. For example, consider the problem of the system response to a student who tries to open the main steam stop before any actions to light off the boiler have been taken. A reminder that the main steam stop should not be opened until steam drum pressure is 400 psi seems fatuous. A more credible response would mention a global landmark state that needed to be accomplished before opening the main steam stop.

There are clear categories of complaints, different classes of which suggest different instructional strategies in their presentation. For example, in response to minor procedural errors, it might be best not to interrupt the student at the time of error commission but, instead, to save the criticism for a debriefing session at the end of the tutorial. Not all of the dependencies are based on the physical constraints of the system itself. Some have to do with safety considerations, and others concern good engineering practice. It might be useful to consider a taxonomy of response strategies for these different types of complaints.

CONCLUSIONS

It is possible to provide considerable tutorial power in a simple system that does not actually simulate the physical plant. A computer-based tutor based on this dependency technique promises to be a fruitful approach to the problems of automating human-like explanation. Without undertaking an extended comparison to all design alternatives, it is nevertheless clear that the technique of using dependency graphs is a substantial advance over frame-oriented CAI. Its power relative to expert systems and qualitative modelling is not yet clear.

FUTURE RESEARCH

The criticism facility has been completed. Another type of tutorial interaction could be achieved by also building a justification facility that a student could use to query the system about the reasons for the sequence of actions in the procedure being what it is. This would be, in effect, an engineering operation sequencing system (EOSS) that could explain itself. At present, it is difficult to elicit the knowledge required to implement such a system from SMEs. It is possible that much of the work of eliciting this knowledge and building the computer code that embodies it could be automated. Such an elicitation facility would make the tutorial techniques developed in this work readily available to a wider community of users.

RECOMMENDATIONS

1. The existing system should be moved to the hardware system that presently supports the STEAMER simulation system.

2. Dependency-based tutorial systems for other procedures should be implemented to test the extensibility of this approach.

3. The problems identified in the attempts to implement the prototype system should be given further attention.

4. The system should be extended so that it will support a justification of the sequence of steps in addition to complaining when legitimate procedural sequence is violated.

REFERENCES

Brown, J. S., Burton, R. R., & deKleer, J. Pedagogical, natural language, and knowledge engineering techniques in SOPHIE I, II, and III. D. Sleeman and J. S. Brown (Eds.). Intelligent Tutoring Systems. New York: Academic Press, 1982.

Carbonnel, J. R. AI in CAI: An artificial-intelligence approach to computer-assisted instruction. IEEE Transactions on Man-Machine Systems, 1970, 190-202.

Forbus, K. D. Project STEAMER: IV. A primer on CONLAN--a constraint-based language for describing the operation of complex physical devices (NPRDC Tech. Note 81-26). San Diego: Navy Personnel Research and Development Center, August 1981.

Forbus, K. D., & Stevens, A. Project STEAMER: III. Using qualitative simulation to generate explanations of how to operate complex physical devices (NPRDC Tech. Note 81-25). San Diego: Navy Personnel Research and Development Center, August 1981.

Hollan, J., Stevens, A., & Williams, M. STEAMER: An advanced computer-assisted instruction system for propulsion engineering. Proceedings of the Summer Computer Simulation Conference, Seattle, 1980.

Roberts, B., & Forbus, K. Project STEAMER: V. Mathematical simulation of STEAMER propulsion plant (NPRDC Tech. Note 81-27). San Diego: Navy Personnel Research and Development Center, August 1981.

Shortliffe, E. H. Computer-based medical consultation, MYCIN. New York: Elsevier/North-Holland, 1976.

Stead, L. Project STEAMER: II. User's manual for the STEAMER interactive graphics package (NPRDC Tech. Note 81-22). San Diego: Navy Personnel Research and Development Center, August 1981.

Stevens, A., Roberts,, B., Stead, L., Forbus, K., Steinberg, C., & Smith, B. Project STEAMER: VI. Advanced computer-aided instruction in propulsion engineering--An interim report (NPRDC Tech. Rep. 82-28). San Diego: Navy Personnel Research and Development Center, January 1982. (AD-A110 797)

Stevens, A., & Steinberg, C. Project STEAMER: I. Taxonomy for generating explanations of how to operate complex physical devices (NPRDC Tech. Note 81-21). San Diego: Navy Personnel Research and Development Center, August 1981.

APPENDIX A

LIGHT-OFF COLD-START

LIGHTOFF COLD-START

Light-off of 1200 psi boiler aboard 1078 class Fast Frigate.

Initial conditions:

Pre-start checks have been completed.

Shore power is on.

Steam is not available.

All equipment in the space is operable.

#1A boiler has been designated for light-off.

M.S. and Aux S. guarding valves are open.

S.H. bleeder guarding valve is open.

Desuperheater inlet is locked open.

Steam drum water level is +4 inches.

Lightoff water sample chemical test readings are:

p.H. = 9.60

Phos. = 12 ppm.

conductivity = 225 mmhos/cm

chloride = 1.0 epm

Fuel oil service tank B.S. & W. readings indicate trace contaminants.

Fuel oil service tank is topped off.

Air atomization is to be used until a steam drum pressure of 400 psi is acheived at which time atomization will be shifted to steam.

DFT water level = 1000 gals.

Reserve and emergency feed tanks are topped off.

Shore steam drains are discharged overboard.

Morpholine injection tank and deionizer are secured.

Boiler stack cover is removed.

Procedure: (location) Action.

1. (boiler) Vent steam drum.
2. (boiler) drain superheater.
3. (console) Start L.P. air compressor and dehydrator.
4. (console) Align L.P. air to A.B.C. system.
5. (boiler) Check safety valve hand-easing gear.
6. (console) Energize and test all alarms.
7. (gage glass) Dump the designated boiler and freshly fill and chemically treat while raising to light-off level.
8. (gage glass) If boiler water chemistry is within limits and water level is greater than or equal to +2 inches then drain the designated boiler to -3 inches and then raise to light-off level.
9. (console) Test A.B.C. system for remote manual operation ensuring movement of final control elements from the console.
10. (boiler) Establish air for boiler purge.
11. (fuel) Align fuel system to #1A boiler using #__ fuel oil service pump and port fuel oil service tank.
12. (fuel) Start #__ fuel oil service pump and check for leaks.
13. (console) Test remote operation of fuel oil quick closing valves.
14. (console) Ensure furnace is purged as required by purge table.
15. (fuel) Assemble atomizer for light-off.
16. (console) Adjust fuel oil supply pressure for air atomization.
17. (boiler) Align L.P. air to #1 burner.
18. (console) Request permission to light fires #1A boiler.
19. (console) Receive orders from EOOW to light fires.
20. (boiler) Light fires in #1A boiler.

21. (boiler) If fires do not light within three seconds, secure burner, remove torch from burner, remove atomizer, check firebox for fuel, and check atomizer assembly before attempting to light fires again.

22. (boiler) If fires do light within three seconds, continue.

23. (boiler) Establish ignition.

24. (console) Report to EOOW fires lit.

25. (console) Set fuel pressure for heating stage.

26. (boiler/console) Switch on burner indicating lights.

27. (console) Maintain a clear stack.

28. (boiler) Check superheater protection bleeder valves.

29. (boiler) Establish pressurization.

30. (feed) Align DFT for warm-up recirculation.

31. (console) Adjust superheater bleeder valve to maintain bleeder pressure at 60 psi.

32. (gage glass) Blowdown boiler water level gage glass.

33. (gage glass/console) Ensure gage glass and remote water level indicator are in agreement.

34. (console) Activate water level alarms.

35. (boiler) Shift superheater drains from F.W. to H.P..

36. (steam) Warm-up main and aux steam piping.

37. (steam) Warm-up piping to 1200/150 reducer.

38. (boiler) When steam drum pressure reaches 400 psi, shift atomization from air to steam.

39. (steam) Open main and aux steam stop valves.

40. (boiler) Shift from motor driven to turbine FDB.

41. (boiler) Light additional burners as required and re-adjust firing rate as necessary.

42. (feed) Align and start main feed pump to boiler.

43. (feed) Place DFT in operation.

44. (feed) Commence feed to the boiler.

45. (feed) Establish water level control.

46. (console) Re-adjust firing rate.

47. (feed) Shift to recovery of F. W. drains and establish DFT level control.

48. (console) When steam drum pressure equals 1000 psi, place feed system in automatic control.

49. (console) Place water level control system in automatic mode.

50. (console) Place FDB control in automatic mode.

51. (console) Place fuel oil control in automatic mode.

52. (console) Ensure operation of boiler in one knob control.

53. (console) Place system in full automatic control.

54. (exit ladder) Call the first steaming watch.

APPENDIX B

JUSTIFICATIONS OF INTERACT DEPENDENCIES

JUSTIFICATIONS OF INTERACT DEPENDENCIES

12-11 Starting the service pump without having systems aligned to take suction from and provide discharge to risks damaging the pump. You won't be able to do much checking for leaks if the pump is not aligned to the piping that is to be checked.

13-12 It is impossible to judge the effectiveness of the fuel oil quick closing valve in the absence of fuel pressure.

16-13 It makes no sense to adjust the fuel oil supply pressure before testing the F.O. quick closing valve since the F.O. service pump will have to be stopped and the valves reset after the test.

14-10 How could the furnace be purged when you haven't even started the forced draft blower yet?

7&8-1 Attempting to change the water level of the steam drum with the air cocks closed is like trying to get gas out of your tank without a vented cap. Draining the drum will create a vacuum in the drum which may unseat the gaskets on the manhole and handhole plates. This could cause leaks when the drum is later pressurized.

Attempting to fill the drum with the air cocks closed would pressurize it and it would be impossible to establish the proper light-off level.

2-1 The steam drum vents should be opened before opening the superheater drains. If bilge level is high and you

open the superheater drains prior to draining down the steam drum with the vents closed, you risk sucking bilge water up through the superheater drains into the superheater. This would require a lengthy clean-up operation and an embarrassing explanation to your C.O.

7&8-5 The safety valve hand easing gear should be checked before adjusting the water level for light-off. If repairs are required to the safety valve hand easing gear, they are likely to be time consuming, and it is poor practice to leave the vents open for extended periods of time.

7&8-6 It is generally a good idea to energize and test alarms before adjusting the water level in the steam drum. Repairs to the alarms are likely to be time consuming and it is good practice to get such things out of the way before the need for the alarm arises.

16-9 It is not absolutely necessary to test the A.B.C. system for remote manual control this early in the light-off procedure, but it is a good idea to check it now, so that if repairs are required, they can be completed before you are committed to more involved activities.

20-14 Attempting to light fires before the furnace is thoroughly purged may result in flare-back due to trapped pockets of combustible gases in the firesides. / BOOM! you just lost your burnerman, messenger, and possibly your

boiler. Sharpen your pencil and rig for paperwork.

9-4 Testing the A.B.C. system for remote manual control obviously requires that the L.P. air be aligned to the A.B.C. system since the entire system is pneumatic in nature.

4-3 Aligning L.P. air to the A.B.C. system cannot be accomplished until the L.P. air compressor has been started.

20-16 Fuel oil supply pressure must be adjusted for the type of atomizer being used before any attempt to light fires is made. In the absence of correct fuel oil pressure, the chances of successfully lighting the fires is greatly reduced.

20-15 The fires cannot be lit until the atomizer is assembled and locked into the burner front.

20-17 The atomizer will not do its job in the absence of an L.P. air supply aligned to the atomizer.

20-7&8 The correct water level and water chemistry must be established before the fires are lit. A water level too high may result in overflow of boiler water into the superheater, contaminating the steam circuit with chemicals. If the water level is too low, you may run out of boiler water before you have enough steam pressure to commence feed to the boiler. If the chemistry is not correct, the probability of tube destruction through corrosion is increased.

18&19-7&8 There is no sense in asking for permission to light fires when correct water level and water chemistry have not been established.

18&19-2 There is no sense in asking for permission to light fires when superheater has not been drained of condensate.

18&19-16 How are you going to light a fire with no fuel?

18&19-14 Do you know what happens when you put a torch in an unpurged boiler?

18&19-17 Hmmm, I thought you were using air atomization. Where is your air supply?

20-18&19 Don't you think the EOOW would like to know what you are up to?

Coordination of the activities in the engineering spaces should be maintained through communication. The EOOW must be informed of all operations taking place in the plant. You must request permission to light fires and receive the order to light fires before proceeding to do so.

23-20 Obviously, the steps involved in establishing ignition should only be taken if the fires have actually lighted.

23-NOT20 IF the fires have not lighted in three seconds, then steps should be taken to secure the plant in such a way

that safety is ensured and restart time is kept to a minimum.

24-23 Report fires lit only when fires have been lit.

26-23 Burner indicator lights should be switched on if and only if combustion has been established.

27-23 Keeping a clear stack is only a problem once combustion has been established.

25-23 The fuel pressure should be set for heating stage only after combustion has been established.

28-23 The problem of protecting the superheater from over heating only arises after combustion has been established.

29-24 If fires are lit, this fact should be reported to the EOOW before proceeding further in the procedure.

29-26 If the fires are lit, the burner indicating lights should be switched on immediately so that both burnerman and console man are aware of the status of the burners.

29-28 Once combustion has been established, the superheater protection bleeder valve should be partially opened before pressurization occurs. This is to ensure steam flow through the superheater to protect the superheater from over heating during the heat-up phase.

36-29 What are you going to warm it up with? Is steam available yet? The steam drum needs to be pressurized before

effective heating of the piping can be accomplished.

35-29 Shifting to high pressure drains before the system is pressurized does not ensure that condensate is removed from the superheater. When pressurization is achieved, a water hammer condition may develop in the high pressure drain piping.

37-36 Attempting to warm up the reducer without warming up the piping first will result in a water hammer condition which may damage the piping.

32-29 The gage glass may drain, but the blow down operation will not be very effective if there is no pressurization of the steam drum to force unwanted impurities from the glass surfaces.

31-29 This adjustment is not possible until boiler steam drum pressure is at least 60 psi.

38c-37 The reducing valve piping must be warmed up before placing the reducer in operation. Failure to do this may result in damage to the reducing valve due to water slugs.

38c-39 The auxiliary steam stop must be opened before the 1200/150 psi reducer can be put in operation.

39-38c Although it is possible to open the main and auxiliary steam stops before the steam drum pressure reaches 400 psi, waiting until 400 psi is reached ensures that

sufficient steam head is available to operate the turbine driven blower and the main feed pump before the water in the boiler becomes dangerously low.

38a-38c Where do you hope to get steam for atomization? The 1200/150 psi reducing valve must be placed in operation (or bypassed) before the shift from air to steam atomization can be made.

39-36 Opening the main and auxiliary steam stops before the piping has been warmed up through the use of the bypass valves risks damaging piping by thermal shock and water hammer.

40-39 How are you going to supply steam to the FDB turbine when the auxiliary steam stops are still closed?

40-38b Starting the turbine driven forced draft blower with less than 400 psi of steam drum pressure produces poor FDB performance at best and risks losing much of the available steam head for nothing. This could lead to a dangerously low water level in the steam drum.

33-32 The gage glass should be blown down to ensure its proper operation before checking that the remote level indicator agrees with the gage glass.

44-33 Since the feed is controlled at the console, the accuracy of the remote water level indicator should be checked before commencing feed to the boiler to ensure that the

console man is controlling what he thinks he is.

44-42 Who or what do you think is going to push feed into a pressurized boiler? The main feed pump must be started before feed to the boiler can be commenced.

44-40 So you want to commence feed? What effect do you anticipate the injection of cold feed into the boiler will have on the steam drum pressure? The firing rate will have to be increased to maintain pressure, but you only have the motor driven FDB in operation and you are already at your maximum firing rate given that limited supply of air. The turbine driven FDB should be placed in operation before commencing feed to the boiler.

41-40 How will you supply air for combustion to the fuel you will supply with these additional burners? The turbine driven FDB should be placed in operation before lighting additional burners.

43-30 The DFT must be warmed-up prior to placing it in operation. The warm-up process removes oxygen from the DFT so that when it is placed in operation and feed to the boiler is commenced, excessive oxygen will not be introduced to the boiler.

44-43 The Deaerating Feed Tank should be placed in operation prior to commencing feed to the boiler. Its purpose is to remove dissolved oxygen from the feed. Failure to do so will result in the introduction of dissolved

oxygen to the boiler where its corrosive effects will damage boiler internal tube surfaces.

45-44 How can you try to control something that is not happening? Establishing water level control assumes that feed to the boiler has already been established.

48-42 How can you put the MFP in automatic control mode when it hasn't even been started yet?

48-48b The main feed pump automatic control system will not operate at steam drum pressures of less than 1000 psi.

49-48 For normal operation placing the water level control in automatic mode requires that the main feed pump be in automatic control mode.

49-45 Placing the water level control in automatic mode requires that the water level first be controlled in remote manual mode.

50b-40 The motor driven FDB has no remote manual control mode. In order to place the FDB in remote manual control mode, the turbine driven FDB must be in operation.

50-50b In order to place the FDB in automatic control mode, it must first be placed in remote manual control mode so that the manual and auto control signals can be matched for shift to auto.

41-38a Lighting additional burners requires that steam atomiza-

tion be available. Since only the number one burner is equipped with L.P. air for atomization, the shift from air to steam atomization will have to take place before lighting additional burners.

52-50 52-51 52-49 Placing the system in one knob control requires that all three major sub-systems (water level, fuel oil pressure, and forced draft blowers) be in automatic control mode with boiler master A/M station in remote manual.

53-52 Placing the system in full automatic control requires that the system first be steady in one knob control.

53- 53a Placing the system in full automatic control requires that the system be maintaining the boiler pressure at setpoint (1275 psi). This enables a smooth transition from remote manual (one knob) to automatic (look Ma no knobs) control.

Light-off complete: O.K. you did it. Now, is the steam pressure steady at 1275 psi? Is the water level normal? Are the forced draft blowers operating within 300 rpm of each other? Is the stack clear? If the answer to any of these questions is negative shift the affected system to remote manual and make appropriate adjustments.

If the answers to all the above questions are true, report status to EOOW and call the steaming watch.

APPENDIX C

SAMPLE PROGRAM INTERACTION

SAMPLE PROGRAM INTERACTION

```
>(order 'open-drum-vents)
```

Drum vents opened.

```
>(order 'establish-water-level)
```

It is generally a good idea to energize and test alarms before adjusting the water level in the steam drum. Repairs to the alarms are likely to be time consuming and it is good practice to get such things out of the way before the need for the alarm arises.

```
>(order 'test-alarms)
```

Alarms test satisfactory.

```
>(order 'establish-water-level)
```

The safety valve hand easing gear should be checked before adjusting the water level for light-off. If repairs are required to the safety valve hand easing gear, they are likely to be time consuming, and it is poor practice to leave the vents open for extended periods of time.

```
>(order 'safety-valve-lifting-gear)
```

Safety valve lifting gear tests satisfactory.

```
>(order 'establish-water-level)
```

Water level is established at +2 inches for lightoff. Lab reports water within chemical limits for lightoff.

```
>(order 'start-electrical-fdb)
```

#1A electrical forced draft blower started. Turbine driven forced draft

draft blower flaps locked closed.

```
>(order 'purge-furnace)
```

Furnace purged in accordance with purge table.

```
>(order 'drain-superheater)
```

Superheater header drains are cracked open.

```
>(order 'align-fuel-system)
```

Fuel oil system aligned to #1A boiler.

```
>(order 'start-fuel-oil-pump)
```

#1A fuel oil service pump started. Recirc valve cracked open. Discharge pressure 350 psi.

```
>(order 'fuel-supply-pressure)
```

It is not absolutely necessary to test the A.B.C. system for remote manual control this early in the light-off procedure, but it is a good idea to check it now, so that if repairs are required, they can be completed before you are committed to more involved activities.

```
>(order 'test-abc-remote-manual)
```

Testing the A.B.C. system for remote manual control obviously requires that the L.P. air be aligned to the A.B.C. system since the entire system is pneumatic in nature.

```
>(order 'start-lp-compressor)
```

Low pressure air compressor started, output pressure gage reads 120 psi.

```
>(order 'align-lp-air-to-abc)
```

Low pressure air supply aligned to automatic combustion control system.

```
>(order 'test-abc-remote-manual)
```

Automatic combustion control system cold checks test satisfactory in remote manual mode. All final control elements show normal movement.

```
>(defprop test-fuel-oil-quick-closing-valves exec stat)
TEST-FUEL-OIL-QUICK-CLOSING-VALVES
```

```
>(order 'fuel-supply-pressure)
```

Fuel oil manifold pressure gage indicates 78 psi.

```
>(order 'assemble-and-insert-atomizer)
```

Atomizer assembled, inspected, inserted into #1 burner position.

```
>(order 'low-press-air-for-atomizer)
```

Low pressure air supply aligned to the atomizer via flexible hose at #1 burner.

```
>(order 'request-permission-light-fires)
```

Light fires in
#1A boiler.

```
>(order 'light-fires)
```

Fires sucessfully lit in #1A boiler on first attempt.

```
>(order 'establish-ignition)
 F.O. root valve fully opened, torch removed from burner and replaced in pot,
F.O. recirc valve closed.

>(order 'establish-pressure)
 If fires are lit, this fact should be reported to the EOOW before
proceeding further in the procedure.

>(order 'report-fires-lit)
 Fires lit , Aye. Bring boiler up to operating pressure in accordance with
normal cold lightoff procedure.


>(order 'burner-indicator-lights)
 Burner indicator lights show fires lit in #1 burner.

>(order 'establish-pressure)
Proper combustion should be maintained during the warmup phase.

>(order 'maintain-proper-combustion)
 Checkman reports periscope clear. Consoleman reports superheater outlet
temperature maintained below 850 degrees.

>(lord 'establish-pressure)
(FUEL-OIL-FOR-HEATING CRACK-SUPERHEATER-BLEEDER-VALVES
                         OBSERVE-STEAM-FORMATION)
>(order 'fuel-oil-for-heating)
 Fuel oil pressure reduced to 50 psi for warm-up stage.
```

```
>(order 'crack-superheater-bleeder-valves)
```

Superheater bleeder valve cracked open and superheater bleeder valve to aux exhaust system fully open.

```
>(order 'observe-steam-formation)
```

It normally takes 30-40 minutes for the steam to form. Steam is now observed flowing from the high and low steam drum vents.

```
>(order 'establish-pressure)
```

High and low steam drum vents closed. Superheater drains throttled. Steam drum pressure gage indicates pressure.

```
>(order 'shift-superheater-drains-to-hp)
```

The steam drum pressure should be allowed to reach 50 psi before the switch to high pressure drains is made. Switching to high pressure drains too early will prevent the complete draining of condensate from the piping.

```
>(pressure)
```

It normally takes about 20 minutes to get 50 psi pressure in the steam drum. Assume that time has passed and the steam drum pressure is now greater than 50 psi.

```
>(order 'shift-superheater-drains-to-hp)
```

Superheater drains shifted to high pressure drain main.

```
>(order 'adjust-superheater-bleeder-pressure)
 Superheater bleeder outlet pressure at 60 psi. Consoleman to control
at 60 psi until main and auxiliary steam stops are open.

>(order 'blow-down-gage-glass)
The gage glass may drain, but the blow down operation will not
be very effective  if there is not at least 100 psi in
the steam drum to force unwanted impurities from the glass surfaces.

>(defprop steam-pressure-100 live stat)
STEAM-PRESSURE-100
>(pressure)
 The steam drum pressure has now risen to 100 psi.

>(order 'blow-down-gage-glass)
Gage glass blown down.

>(defprop blow-down-gage-glass (princ '| Gage glass blowndown.|) aname)
BLOW-DOWN-GAGE-GLASS

>(order 'blow-down-gage-glass)
 Already executed, Sir!

>(order 'verify-water-level-indicators)
 Checkman and consoleman verify that remote and direct water level
indicators are in agreement.

>(order 'warm-up-ms-piping)
```

Main and auxiliary steam bypass valves on #1A boiler are cracked open.

>(order 'warm-up-reducer-piping)

Auxiliary steam valve to 1200150 psi reducer opened, fresh water drain valve cracked open at reducer inlet.

>(order 'open-steam-stops)

Although it is possible to open the main and auxiliary steam stops before the steam drum pressure reaches 400 psi, waiting until 400 psi is reached ensures that sufficient steam head is available to operate the turbine driven blower and the main feed pump before the water in the boiler becomes dangerously low.

>(pressure)

The steam drum pressure has now risen to 400 psi.

>(order 'open-steam-stops)

Main and auxiliary steam stops opened #1A boiler, bypass valves closed, fresh water drains shifted to H.P.

>(order 'start-fdb-local-manual)

#1A1 forced draft blower in local manual operation at 1100 rpm.

APPENDIX D

LIGHT-OFF PROGRAM LISTING

LIGHTOFF PROGRAM LISTING

```
(defprop mfp-remote-manual live stat)
(defprop start-fdb-local-manual live stat)
(defprop full-auto live stat)
(defprop one-knob-control live stat)
(defprop steam-pressure-1275 live stat)
(defprop water-level-auto live stat)
(defprop fuel-oil-auto live stat)
(defprop fdb-auto live stat)
(defprop mfp-auto live stat)
(defprop water-level-remote-manual live stat)
(defprop steam-pressure-1000 live stat)
(defprop start-mfp live stat)
(defprop water-level-alarms live stat)
(defprop fdb-remote-manual live stat)
(defprop commence-feed live stat)
(defprop start-dft live stat)
(defprop verify-water-level-indicators live stat)
(defprop warm-recirc-dft live stat)
(defprop blow-down-gage-glass live stat)
(defprop establish-pressure live stat)
(defprop report-fires-lit live stat)
(defprop burner-indicator-lights live stat)
(defprop maintain-proper-combustion live stat)
(defprop fuel-oil-for-heating live stat)
(defprop crack-superheater-bleeder-valves live stat)
(defprop observe-steam-formation live stat)
(defprop establish-ignition live stat)
(defprop light-fires live stat)
(defprop drain-superheater live stat)
(defprop assemble-and-insert-atomizer live stat)
(defprop low-press-air-for-atomizer live stat)
(defprop receive-order-to-light-fires live stat)
(defprop request-permission-light-fires live stat)
(defprop establish-water-level live stat)
(defprop fuel-supply-pressure live stat)
(defprop purge-furnace live stat)
(defprop test-alarms live stat)
(defprop safety-valve-lifting-gear live stat)
(defprop open-drum-vents live stat)
(defprop start-lp-compressor live stat)
(defprop start-electrical-fdb live stat)
(defprop test-abc-remote-manual live stat)
(defprop test-fuel-oil-quick-closing-valves live stat)
(defprop start-fuel-oil-pump live stat)
(defprop align-fuel-system live stat)
(defprop align-lp-air-to-abc live stat)
(defprop shift-motor/turbine-fdb live stat)
(defprop open-steam-stops live stat)
(defprop steam-pressure-400 live stat)
(defprop warm-up-ms-piping live stat)
```

```
(defprop light-additional-burners live stat)
(defprop shift-air/steam-atomization live stat)
(defprop start-1200/150-reducer live stat)
(defprop warm-up-reducer-piping live stat)
(defprop shift-superheater-drains-to-hp live stat)
(defprop steam-pressure-50 live stat)
(defprop adjust-superheater-bleeder-pressure live stat)


(setq
r12-11 "Starting the service pump without having systems aligned to
take suction from and provide discharge to risks damaging the pump.
You won't be able to do much checking for leaks if the pump is not
aligned to the piping that is to be checked.
")
(setq
r13-12 "It is impossible to judge the effectiveness of the
fuel oil quick closing valve in the absence of fuel pressure.
So start the pump first.
")
(setq
r16-8 "The air lines will not have any pressure until the
compressor has been started.
")
(setq
r14-13 "It makes no sense to adjust the fuel oil supply pressure
before testing the F.O. quick closing valve since the F.O. service
pump will have to be stopped and the valves reset after the test.
")
(setq
r7-6 "How could the furnace be purged when you haven't even started the
forced draft blower yet?
")
(setq
r4-1 "Attempting to change the water level of the steam drum with the
air cocks closed is like trying to get gas out of your tank without a
vented cap. Draining the drum will create a vacuum in the drum which may
unseat the gaskets on the manhole and handhole plates. This could cause
leaks when the drum is later pressurized.
  Attempting to fill the drum  with the air
cocks closed
would pressurize it and it would be impossible to establish the proper
light-off level.
")
(setq
r4-3 "The safety valve hand easing gear should be checked before adjusting
the water level for light-off.  If repairs are required to the safety valve
hand easing gear, they are likely to be time consuming, and it is poor
practice to leave the vents open for extended periods of time.
")
(setq
r4-2 "It is generally a good idea to energize and test alarms before
adjusting the water level in the steam drum.  Repairs to the alarms are
likely to be time consuming and it is good practice to get such things out
```

```
of the way before the need for the alarm arises.
")
(setq
r14-10 "It is not absolutely necessary to test the A.B.C. system for
remote manual control this early in the light-off procedure, but it
is a good idea to check it now, so that if repairs are required, they
can be completed before you are committed to more involved activities.
")
(setq
r10-9 "Testing the A.B.C. system for remote manual control obviously requires
that the L.P. air be aligned to the A.B.C. system since the entire system is
pneumatic in nature.
")
(setq
r9-8 "Aligning L.P. air to the A.B.C. system cannot be accomplished
until the L.P. air compressor has been started.
")
(setq
r17-14 "Fuel oil supply pressure must be adjusted for the type of
atomizer being used before any attempt to light fires is made.
In the absence of correct fuel oil pressure, the chances of successfully
lighting the fires is greatly reduced.
")
(setq
r16-15 "Air cannot be aligned to the atomizer
 until the atomizer is assembled and secured
into the burner front.
")
(setq
r17-16 "You run the risk of causing a boiler explosion if you attempt
to light fires without atomizing air aligned to the burner.  The
pressure must be appropriate for the atomizer in use.
This alignment should be completed before you request premission to
light fires.
")
(setq
r17-4 "There is no sense in asking for permission to light fires when
correct water level and water chemistry have not been established.
A water level too high may result in overflow of
boiler water into the superheater, contaminating the steam circuit with
chemicals.  If the water level is too low, you may run out of boiler water
before you have enough steam pressure to commence feed to the boiler.  If the
chemistry is not correct, the probability of tube destruction through
corrosion is increased.
")

(setq
r17-5 "Better not attempt to light fires when
superheater has not been drained of condensate. This could give your
drain piping a bad case of the squirts.
")
(setq
r17-14 "How are you going to light a fire with no fuel?
")
```

```
(setq
r17-7 "Do you know what happens when you put a torch in an unpurged boiler?
Attempting to light fires before the furnace is thoroughly purged
may result in flare-back due to trapped pockets of combustible gases in the
firesides. / BOOM! you just lost your burnerman, messenger, and possibly your
boiler. Sharpen your pencil and rig for paperwork.
")
(setq
r19-17 " You must request permission to light fires and receive the
order to light fires before proceeding to do so.
")
(setq
r20-19 "Obviously, the steps involved in establishing ignition should
only be taken if the fires have actually lighted.
")
(setq
r21-20 "Report fires lit only when ignition has been established.
")
(setq
r22-20 "Burner indicator lights should be switched on if and only if
combustion has been established.
")
(setq
r22-21 "Fires should be reported lit before the burner indicator lights
are switched on.
")
(setq
r23-22 "The console man should set the fuel pressure for heating only after
he has verified that the burner indicator light is on.
")
(setq
r24-20 "Keeping a clear stack is only a problem once combustion has been
established.
")
(setq
r23-20 "The fuel pressure should be set for heating stage only after
combustion has  been established.
")
(setq
r25-20 "The problem of protecting the superheater
from over heating only arises after combustion has been established.
")
(setq
r26-20 "You are not likely to observe steam formation before ignition is
established in the furnace.
")
(setq
r27-20 "Don't close those vents yet dummy! You aren't even sure your
fires will stay lit yet.
")
(setq
r27-21 "If fires are lit, this fact should be reported to the EOOW before
proceeding further in the procedure.
")
```

```
(setq
r27-22 "If the fires are lit, the burner indicating lights should be switched
on immediately so that both burnerman and console man are aware of the
status of the burners.
")
(setq
r27-24 "Proper combustion should be maintained during the warmup
phase.
")
(setq
r27-23 "The fuel oil supply pressure should be set for heating stage
before pressurization is established.
")
(setq
r27-26 "You should observe steam formation before closing the vents
to establish pressurization.  Failure to do so could leave non-condensable
oxygen inside the boiler.
")
(setq
r27-25 "Once combustion has been established, the superheater protection
bleeder
valve should be partially opened before pressurization occurs. This is to
ensure steam flow through the superheater to protect the superheater from
over heating
during the heat-up phase.
")
(setq
r34-31 " Warming the piping requires drawing steam from the steam drum.
If you do this before you have sufficient pressure on the drum, you may
cause a substantial delay in the pressure build up.")
(setq
r35-34 "Attempting to warm up the reducer without warming up the piping
first will result in a water hammer condition which may damage the
piping.
")
(setq
r32-31 "The gage glass may drain, but the blow down operation will not
be very effective  if there is not at least 100 psi in
the steam drum to force unwanted impurities from the glass surfaces.
")
(setq
r36-29 "The superheater drains which are now draining to the bilges
should be shifted to high pressure drains in order to permit the
buildup of greater pressures in the steam circuit. Otherwise
the space will fill with steam and a pressure of 400 psi will
never be reached without overfiring the superheater.
")
(setq
r30-28 "The superheater bleeder pressure is to be adjusted to 60 psi.
There will be no way to set that pressure until after the steam
drum pressure has reached at least 60 psi.
")
(setq
r29-28 "The steam drum pressure should be allowed to reach 50 psi
```

```
before the switch to high pressure drains is made. Switching to
high pressure drains too early will prevent the complete draining of
condensate from the piping.
")
(setq
r38-35 "The reducing valve piping must be warmed up before placing
the reducer in operation. Failure to do this may result in damage to the
reducing valve due to water slugs.
")
(setq
r38-37 "The auxiliary steam stop must be opened before the 1200/150
psi reducer can be put in operation.
")
(setq
r37-36 "Although it is possible to open the main and auxiliary steam
stops before  the steam drum pressure reaches 400 psi, waiting until
400 psi is reached ensures that sufficient steam head is available to
operate the turbine driven blower and the main feed pump before the
water in the boiler becomes dangerously low.
")
(setq
r42-38 "Where do you hope to get steam for atomization?  The 1200/150
psi reducing valve must be placed in operation (or bypassed) before
the shift from air to steam atomization can be made.
")
(setq
r42-41 "The shift from air to steam atomization requires that two burners
be lit at the same time.  The motor driven forced draft blower does not
have sufficient capacity to support two burner operation. Attempting to
change from air to steam atomization without the turbine driven FDB in
operation will lead to the production of heavy black smoke.")
(setq
r37-34 "Opening the main and auxiliary steam stops before the piping
has been warmed up through the use of the bypass valves risks damaging
piping by thermal shock and water hammer.
")
(setq
r41-37 "How are you going to supply steam to the FDB turbine when
the auxiliary steam stops are still closed?
")
(setq
r41-36 "Starting the turbine driven forced draft blower with less
than 400 psi of steam drum pressure produces poor FDB performance at best
and risks losing much of the available steam head for nothing.  This could
lead to a dangerously low water level in the steam drum.
")
(setq
r33-32 "The gage glass should be blown down to ensure its proper operation
before checking that the remote level indicator agrees with the gage glass.
")
(setq
r46-45 "Better energize the water level alarms before starting the MFP.
Otherwise you may end up with high water in the boiler.
")
```

```
(setq
r47-33 "Since the feed is controlled at the console, the accuracy of the
remote water level indicator should be checked before commencing feed to
the boiler to ensure that the console man is controlling what he thinks
he is.
")
(setq
r47-46 "Who or what do you think is going to push feed into a
pressurized boiler?  The main feed pump must be started before
feed to the boiler can be commenced.
")
(setq
r47-41 "So you want to commence feed?  What effect do you anticipate
the injection of cold feed into the boiler will have on the
steam drum pressure? The firing rate will have to be increased
to maintain pressure, but you only have the motor driven FDB
in operation and you are already at your maximum firing rate
given that limited supply of air. The turbine driven FDB should
be placed in operation before commencing feed to the boiler.
")
(setq
r48-41 "How will you supply air for combustion to the fuel you will
supply with these additional burners?  The turbine driven FDB should
be placed in operation before lighting additional burners.
")
(setq
r44-43 "The DFT must be warmed-up prior to placing it in operation.
The warm-up process removes oxygen from the DFT so that when it is
placed in operation and feed to the boiler is commenced, excessive
oxygen will not be introduced to the boiler.
")
(setq
r47-44 "The Deaerating Feed Tank should be placed in operation
prior to commencing feed to the boiler.  Its purpose is to
remove dissolved oxygen from the feed.  Failure to do so will result
in the introduction of dissolved oxygen to the boiler where its
corrosive effects will damage boiler internal tube surfaces.
")

(setq
r50-47 "How can you try to control something that is not happening?
Establishing water level control assumes that feed to the boiler
has already been established.
")
(setq
r51-46 "How can you put the MFP in remote manual control mode when it
hasn't even been started yet?
")
(setq
r53-51 " Main feed pump must be controlled in remote manual mode prior
to placing it in automatic control. This permits the matching of the
manual and automatic control signals to effect a smooth transition.")
(setq
r53-52 "The main feed pump automatic control system will not operate
```

```
at steam drum pressures of less than 1000 psi.
")
(setq
r54-53 "For normal operation  placing the water level control
in automatic mode requires that
the main feed pump be in automatic control mode.
")
(setq
r54-50 "Placing the water level control in automatic mode requires that
the water level first be controlled  in remote manual mode.
")
(setq
r40-39 "The motor driven FDB has no remote manual control mode. In order to
place the FDB in remote manual control mode, the turbine driven FDB must
be in operation.
")
(setq
r41-40 "In order to shift from motor driven to turbine driven FDB,
the turbine driven FDB must first be started, warmed-up, and
placed in remote manual control to allow the consoleman control of
combustion air during the stopping of the motor driven FDB.
")
(setq
r49-41 " In order to place the FDB in automatic control, the shift from
motor driven to turbine driven FDB must have been made. The motor driven
FDB operates at a set speed and has no control mechanisms.
")
(setq
r48-42 "Lighting additional burners requires that steam atomization be
available.  Since only the number one burner is equipped with L.P. air
for atomization, the shift from air to steam atomization will have to
take place before lighting additional burners.
")
(setq
r55-49 "Before placing the fuel oil control valve in semi-automatic
mode, the FDB must be placed in semi-automatic mode. Failure to do so
may result in a surge in control signals running the risk of a flareback.
")
(setq
r56-55 "In order to verify operation in one knob control, both the fuel
system and the air system must be in semi-automatic mode.
")
(setq
r58-56 "Placing the system in full automatic control requires that the system
first be steady in one knob control.
")
(setq
r58-57 "Placing the system in full automatic control requires that the
system be maintaining the boiler pressure at setpoint (1275 psi).  This
enables a smooth transition from remote manual (one knob) to automatic
(look Ma no knobs) control.
")
(setq
r58-54  " Placing the system in full automatic mode requires tht the
```

```
water level control be operating in automatic mode.
")

(defprop full-auto r58-57 steam-pressure-1275)
(defprop full-auto r58-56  one-knob-control)
(defprop full-auto r58-54  water-level-auto)
(defprop one-knob-control r56-55  fuel-oil-auto)
(defprop steam-pressure-1275 r57-52 steam-pressure-1000)
(defprop fuel-oil-auto r55-49 fdb-auto)
(defprop water-level-auto r54-53  mfp-auto)
(defprop water-level-auto r54-50  water-level-remote-manual)
(defprop mfp-auto r53-52  steam-pressure-1000)
(defprop mfp-auto r53-51 mfp-remote-manual)
(defprop mfp-remote-manual r51-46 start-mfp)
(defprop start-mfp r46-45  water-level-alarms)
(defprop water-level-remote-manual  r50-47  commence-feed)
(defprop commence-feed  r47-33   check-level-indicators)
(defprop commence-feed  r47-41   shift-motor/turbine-fdb)
(defprop commence-feed  r47-44   start-dft)
(defprop commence-feed  r47-46   start-mfp)
(defprop start-dft  r44-43  warm-recirc-dft)
(defprop check-level-indicators  r33-32  blow-down-gage-glass)
(defprop blow-down-gage-glass  r32-31  steam-pressure-100)
(defprop steam-pressure-100 r31-30 adjust-superheater-bleeder-pressure)
(defprop steam-pressure-100  r31-28  steam-pressure-50)
(defprop fdb-auto r49-41 shift-motor/turbine-fdb)
(defprop fdb-auto r49-47 commence-feed)
(defprop shift-motor/turbine-fdb r41-40 fdb-remote-manual)
(defprop fdb-remote-manual r40-39 start-fdb-local-manual)
(defprop establish-pressure r27-20 establish-ignition)
(defprop establish-pressure  r27-21  report-fires-lit)
(defprop establish-pressure  r27-22  burner-indicator-lights)
(defprop establish-pressure  r27-24  maintain-proper-combustion)
(defprop establish-pressure  r27-23  fuel-oil-for-heating)
(defprop establish-pressure  r27-25  crack-superheater-bleeder-valves)
(defprop establish-pressure  r27-26  observe-steam-formation)
(defprop report-fires-lit  r21-20  establish-ignition)
(defprop burner-indicator-lights  r22-20  establish-ignition)
(defprop burner-indicator-lights  r22-21  report-fires-lit)
(defprop maintain-proper-combustion  r24-20  establish-ignition)
(defprop fuel-oil-for-heating  r23-20  establish-ignition)
(defprop fuel-oil-for-heating r23-22  burner-indicator-lights)
(defprop crack-superheater-bleeder-valves  r25-20  establish-ignition)
(defprop crack-superheater-bleeder-valves  r25-21  report-fires-lit)
(defprop observe-steam-formation  r26-20  establish-ignition)
(defprop observe-steam-formation  r26-23  fuel-oil-for-heating)
(defprop establish-ignition  r20-19  light-fires)
(defprop light-fires r19-17  request-permission-light-fires)
(defprop request-permission-light-fires  r17-4  establish-water-level)
(defprop request-permission-light-fires  r17-5 drain-superheater)
(defprop request-permission-light-fires  r17-7  purge-furnace)
(defprop request-permission-light-fires  r17-14  fuel-supply-pressure)
(defprop request-permission-light-fires   r17-16  low-press-air-for-atomizer)
(defprop establish-water-level  r4-1  open-drum-vents)
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(defprop establish-water-level  r4-2  test-alarms)
(defprop establish-water-level  r4-3  safety-valve-lifting-gear)
(defprop drain-superheater  r5-1  open-drum-vents)
(defprop low-press-air-for-atomizer  r16-8  start-lp-compressor)
(defprop low-press-air-for-atomizer  r16-15  assemble-and-insert-atomizer)
(defprop purge-furnace  r7-6  start-electrical-fdb)
(defprop fuel-supply-pressure  r14-10  test-abc-remote-manual)
(defprop fuel-supply-pressure  r14-13  test-fuel-oil-quick-closing-valves)
(defprop test-fuel-oil-quick-closing-valves  r13-12  start-fuel-oil-pump)
(defprop start-fuel-oil-pump  r12-11  align-fuel-system)
(defprop test-abc-remote-manual  r10-9  align-lp-air-to-abc)
(defprop align-lp-air-to-abc  r9-8  start-lp-compressor)
(defprop shift-motor/turbine-fdb  r41-37  open-steam-stops)
(defprop shift-motor/turbine-fdb r41-36  steam-pressure-400)
(defprop open-steam-stops  r37-34  warm-up-ms-piping)
(defprop warm-up-ms-piping r34-31  steam-pressure-100)
(defprop open-steam-stops  r37-36  steam-pressure-400)
(defprop steam-pressure-1000  r52-36  steam-pressure-400)
(defprop steam-pressure-400  r36-31 steam-pressure-100)
(defprop light-additional-burners  r48-41  shift-motor/turbine-fdb)
(defprop light-additional-burners  r48-42  shift-air/steam-atomization)
(defprop shift-air/steam-atomization  r42-38  start-1200/150-reducer)
(defprop shift-air/steam-atomization  r42-37  open-steam-stops)
(defprop start-1200/150-reducer  r38-35  warm-up-reducer-piping)
(defprop start-1200/150-reducer  r38-37  open-steam-stops)
(defprop warm-up-reducer-piping  r35-34  warm-up-ms-piping)
(defprop warm-up-ms-piping  r34-31  steam-pressure-100)
(defprop steam-pressure-400  r36-29  shift-superheater-drains-to-hp)
(defprop shift-superheater-drains-to-hp  r29-28  steam-pressure-50)
(defprop adjust-superheater-bleeder-pressure  r30-28 steam-pressure-50)


(defun livep (a)
  (cond ((equal (get a 'stat) 'exec) nil)
        (T) ))

(defun order (act)
(clear lisp-window)
(cond ((null act) (meta-samp)))
(setq priors nil)
(cond ((null (get act 'stat)) (princ '|Sorry, I don't recognize |)act)
      ((not(livep act)) (princ '|Already executed, Sir!|))
      ((livepriors (plist act))
       (princ (eval (get act (car (livepriors(plist act)))))));req remains
      (T (putprop act 'exec 'stat);make it done
         (eval (fconcs(plist act))); effect consequences
         (terpri)
         (princ (eval (get act 'aname))))) ;acknowledge order executed


(defun lord (act)
(setq priors nil)
   (livepriors (plist act)))
```

```
(defun livepriors (l)
       (cond ((null l) priors)
             ((equal (car (explode (cadr l))) 'r)
              (cond ((livep (car l))
                     (setq priors (append (list (car l)) priors))
                     (livepriors (cddr l)))
                    (T (livepriors (cddr l)))))
             (T (livepriors (cddr l))) ))


(defun fpriors (l)
  (cond ((null l) priors)
 ((equal (car (explode (cadr l))) 'r)
        (setq priors (append (list (car l)) priors))
              (fpriors (cddr l)))
       (T (fpriors (cddr l)))))

(defun fconcs (l)
  (cond ((null l) nil)
        ((equal (car l) 'conseq) (cadr l))
        (T (fconcs (cddr l)))))

(defun pressure ()
       (order (liveprip presslist)))

(defun liveprip (l)
       (cond ((null l) nil)
             ((livep (car l)) (car l))
             (T (liveprip (cdr l)))))

(setq presslist '(establish-pressure steam-pressure-50
                                     steam-pressure-100
                                     steam-pressure-400
                                     steam-pressure-1000
                                     steam-pressure-1275))
```

END

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